NASA TECH BRIEF

Langley Research Center

Wide Deviation Phase Modulator

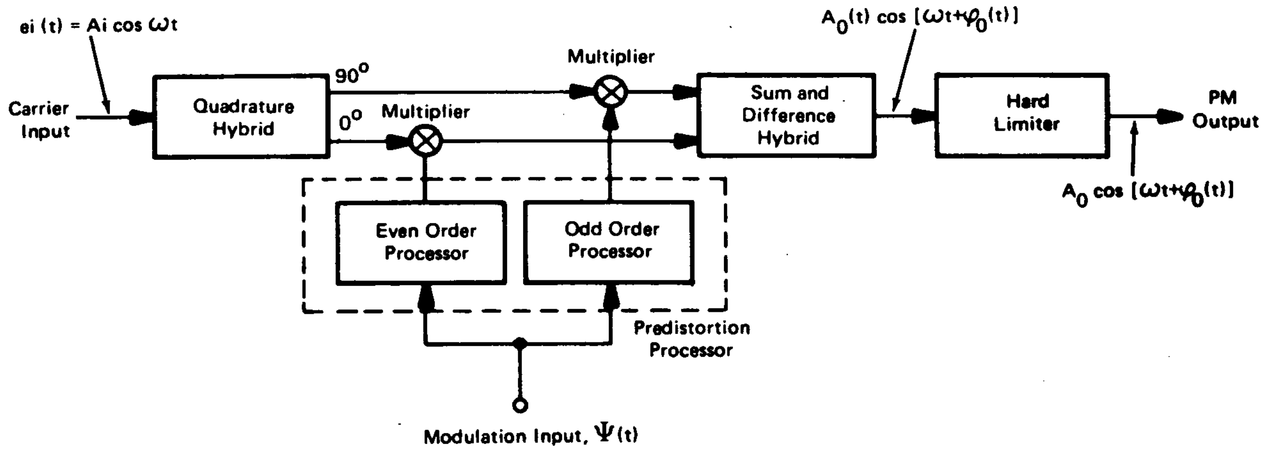

Figure 1. Functional Diagram of Phase Modulator

A modulator was designed to produce a phase-modulated (PM) waveform having high modulating linearity. Practical circuits utilizing the technique described have been constructed and evaluated for peak phase deviations as large as 5 radians. Additionally, the technique is inherently wideband with respect to carrier frequency and can operate over a decade carrier frequency range without adjustments. Circuit performance is both mathematically predictable and highly reproducible.

Mathematically, an ideal PM waveform may be expressed as

$$e(t) = \mathrm{Re}\left\{Ae^{j[\omega t+\Psi(t)]}\right\} \qquad (1)$$

where A is the carrier amplitude, ω is the carrier radian frequency, and $\Psi(t)$ is the modulating function. Equation 1 can be rewritten as either

$$e(t) = [A\cos\omega t\cos\Psi(t)] - [A\sin\omega t\sin\Psi(t)] \qquad (2)$$

or

$$e(t) = A\left[1-\frac{\Psi^2(t)}{2!}+\frac{\Psi^4(t)}{4!}-\ldots\right]\cos\omega t - A\left[\Psi(t)-\frac{\Psi^3(t)}{3!}+\frac{\Psi^5(t)}{5!}-\ldots\right]\sin\omega t \qquad (3)$$

The configuration shown in Figure 1 performs the operations indicated in equations 2 and 3. Sine and cosine modules are commercially available; however, they are at present two-quadrant (±90°) devices. This technique uses truncated power series processors and determines the coefficients for producing the best modulating linearity. The modulated phase of e(t), $\varphi_0(\Psi)$, is

$$\varphi_0(\Psi) = \tan^{-1}\left[\frac{\Psi-k_3\Psi^3+k_5\Psi^5-\ldots}{1-k_2\Psi^2+k_4\Psi^4-\ldots}\right] \qquad (4)$$

(continued overleaf)

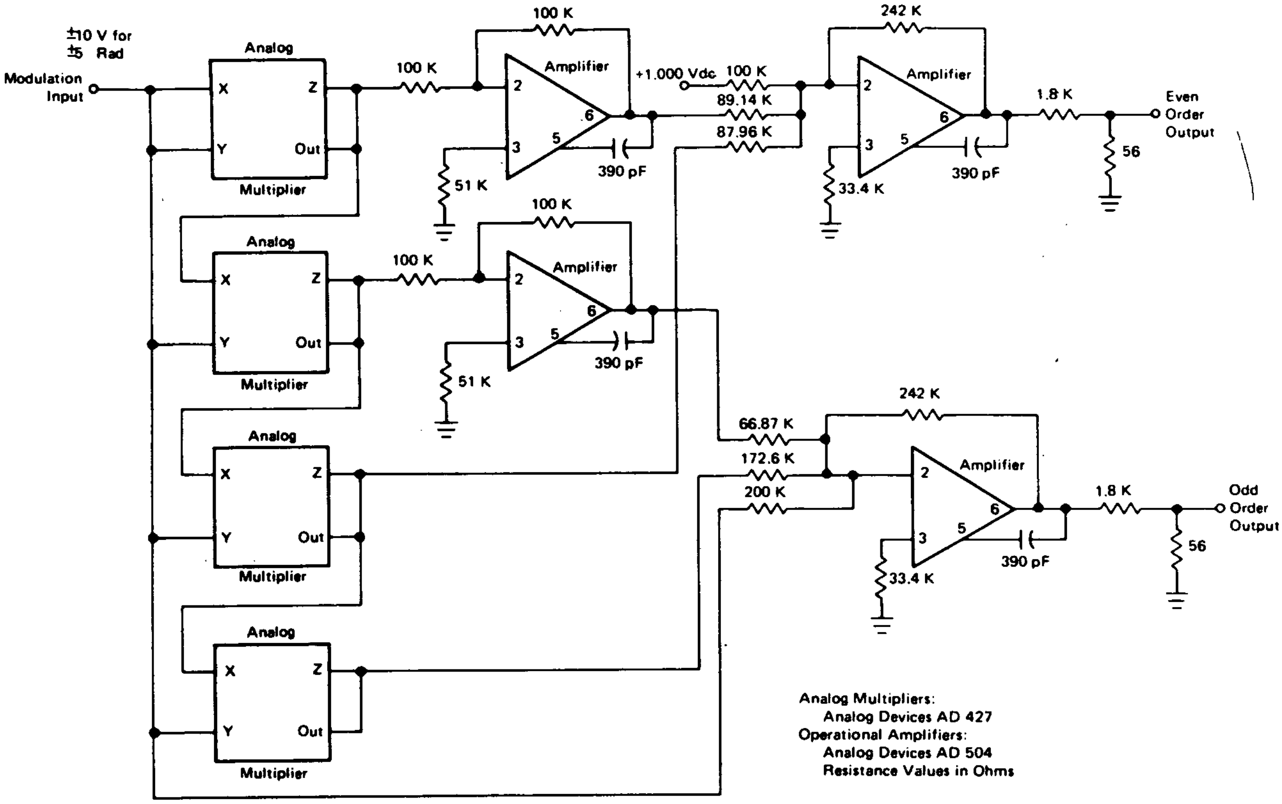

Figure 2. Fifth Order Processor for ±5 Radians

where the k_i are the coefficients of the nonlinear processors and should be chosen to make $\varphi_0(\Psi)$ a best approximation to Ψ. Optimization can be based on various criteria. Two commonly used criteria are minimum mean square error (MMSE) between $\varphi_0(\Psi)$ and Ψ and minimum total harmonic distortion (MTHD) for Ψ a sinusoidal signal. Computer programs have been developed to minimize the integral expressions defining MSE and THD for an arbitrary number of independent variables.

Figure 2 is the diagram of a fifth order MMSE predistortion processor designed for ±5 radians. The optimum coefficients are: $k_2 = 0.448754$, $k_3 = 0.119633$, $k_4 = 0.0181933$, and $k_5 = 0.00185463$. Considerable care should be used in component selection and application. Resistors were trimmed to 0.1 percent, and the balanced mixers were slope matched to about 1 percent. Residual amplitude modulation (AM) on the order of 12 dB was fully suppressed with a limiter which exhibited negligible AM-to-PM conversion. Whereas theory predicts the fifth order MMSE realization should show a maximum deviation of 1° from the best straight line, the measured data for a practical circuit showed a 4.6° deviation or 1.6 percent of full scale. The upper modulation frequency response for this circuit was limited to about 25 kHz by the operational amplifiers.

Note:

No further documentation is available. Specific questions, however, may be directed to:

Technology Utilization Officer
Langley Research Center
Mail Stop 139-A
Hampton, Virginia 23665
Reference: B74-10178

Patent status:

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel
Langley Research Center
Mail Stop 456
Hampton, Virginia 23665

Source: Richard H. Couch and Chase P. Hearn
Langley Research Center
and Lewis R. Wilson of
LTV Aerospace Corp.
under contract to
Langley Research Center
(LAR-11607)